NONACTINIDE ISOTOPES
AND SEALED SOURCES
MANAGEMENT GROUP

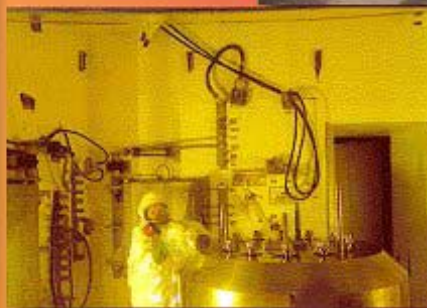# Addendum #1
Cesium–Strontium (Cs/Sr) Management
Alternatives Trade Study

Complexwide Resources Solving Site Specific Problems

U.S. Department of Energy
May, 2002

EXECUTIVE SUMMARY

Evaluation of a sixth alternative for the Cesium-Strontium Management Alternatives Trade Study of July 2001 (DOE, 2001a) has resulted in a change in the preferred alternative. Alternative 6, Secure Subsurface Storage, shown in Table ES-1, provides secure, long-term storage of the WESF capsules in an onsite storage facility at Hanford.

	Alternative	Description
1	**Baseline**	Vitrify WESF inventory in Phase 2 of WTP and LLW disposal for remaining items. No identified disposition for Oak Ridge RTGs and other items.
2	**Consolidation for Disposition**	Consolidate materials at Hanford to optimize disposition.
3	**National Resource Consolidation**	Consolidate materials at Hanford and manage for commercial use or national resource reserve.
4	**Existing Facility Utilization**	Utilize existing DOE resources at Hanford and Savannah River Site (SRS) to process material for disposition.
5	**Disposition Before Consolidation**	Reduce inventory of material through LLW disposal and consolidate remaining items at Hanford.
6	**Secure Sub-Surface Storage**	**Transfer WESF inventory to a secure, long-term, underground storage facility at Hanford. LLW disposal for remaining items. No identified disposition for Oak Ridge RTGs and some other items.**

Table ES-1. Disposition Alternatives.

This alternative removes the capsules from the actively cooled pool storage of the Waste Encapsulation and Storage Facility (WESF) in the shortest time frame, approximately 10 years sooner than the baseline and places the material in a secure, lined and monitored subsurface storage facility. The capsules would be placed into High Integrity Containers (HIC) with a design life of 300 years prior to placement in the retrievable subsurface facility. The long-term storage of the material results in a significant cost savings (see Table ES-2) over the remaining five alternatives with consideration of the required monitoring and maintenance for 300 years.

Table ES-2. Cost Summary for the Six Decision Alternatives.

	Alternative (costs in $ Million)					
Category	1	2	3	4	5	6
Capital	30	51	50	71	51	17
Operations	193	227	302	227	226	123
Transportation	0	2.6	2.6	20.5	2.6	0
Disposal	0.9	0.9	0.1	0.9	0.9	0
Total Life Cycle Cost	**224**	**281**	**355**	**319**	**281**	**140**

The decision method, selection of evaluation criteria, and the scoring method used in this addendum were the same as in the July 2001 Trade Study and are based on standard sources of decision methodology, including the Guidebook to Decision-Making Methods (DOE 2001b). Figure ES-1 summarizes the normalized scores for the nine discriminating criteria used to evaluate the six alternatives in the decision analysis. The results indicate that the secure subsurface storage alternative is the preferred alternative with a score of 77.2%. The previous preferred alternative was the current baseline with a score of 70.7%.
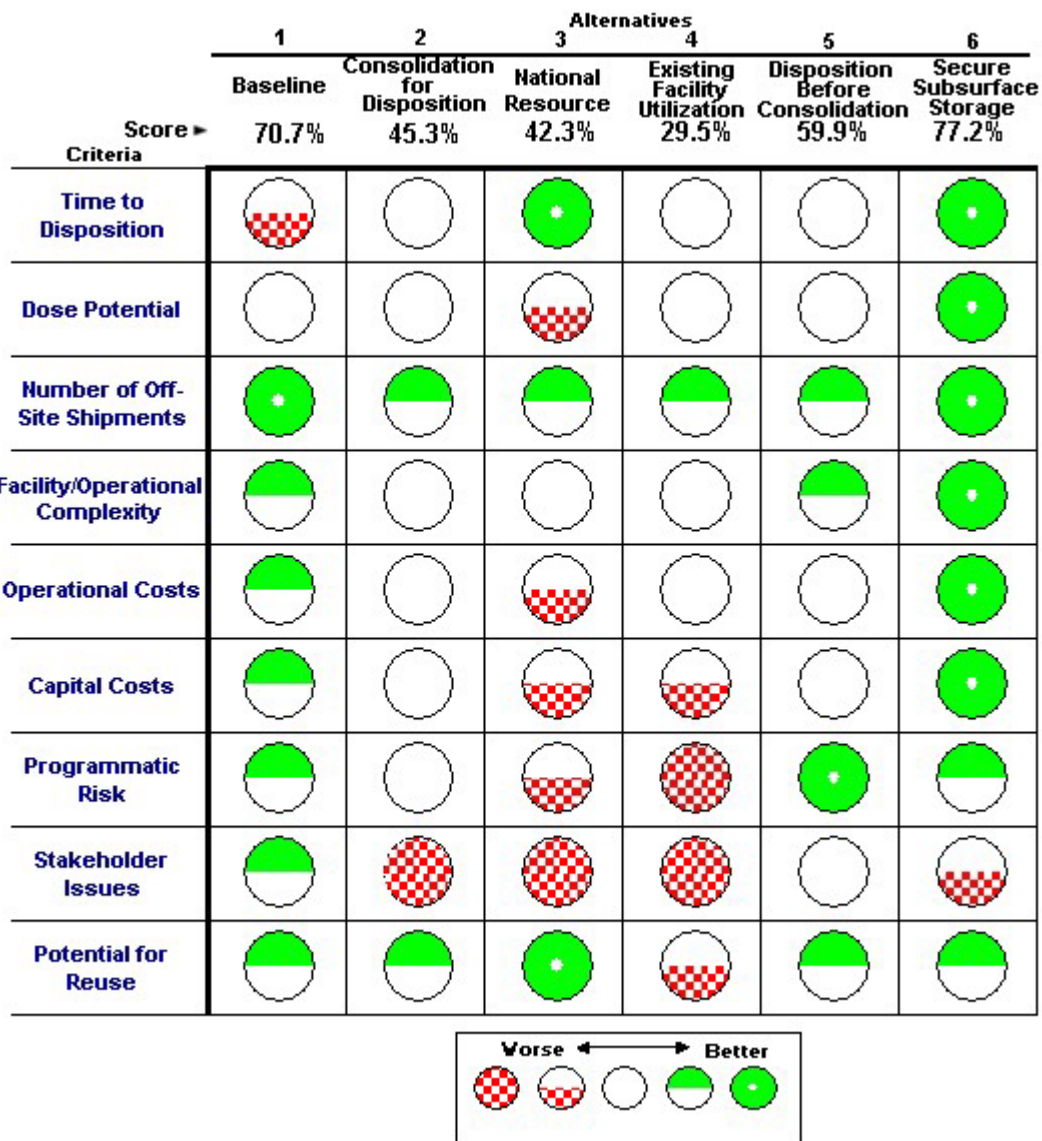
Figure ES-1. Alternative Scoring Result Summary.
Use of formal methodology provides a transparent and defensible evaluation.

The long-term storage alternative presents significant cost reduction opportunities and dispositions 99% of the total Cs/Sr inventory in the most expedient manner. There are clearly some stakeholder issues that would need to be addressed for long-term onsite storage. Considering the potential security and cost saving benefits, a detailed evaluation directed at the application of secure subsurface storage is recommended.

Addendum #1
Cesium Strontium Management Alternatives Trade Study

1.0 Purpose

The purpose of this addendum is to supplement the Cesium-Strontium (Cs/Sr) Management Alternatives Trade Study (DOE, 2001a) (Trade Study) through the addition of an alternative that considers a long-term secure storage strategy for the Cs/Sr inventory currently in storage at the Waste Encapsulation and Storage Facility (WESF). The recent Top Down Review supports the development of risk-based decisions and provides a basis for consideration of a long-term storage alternative. This evaluation implements the same decision process utilized in the Trade Study to support a determination if significant risk reduction or cost savings can be achieved through alternative inventory management.

2.0 Background

The Cesium-Strontium (Cs/Sr) Management Alternatives Trade Study (DOE, 2001a) provided an evaluation of the first five alternatives identified in Table 2-1. Alternative 6 has been added for Addendum #1.

<table>
<tr><th colspan="3">Table 2-1. Disposition Alternatives.</th></tr>
<tr><th></th><th>Alternative</th><th>Description</th></tr>
<tr><td>1</td><td>Baseline</td><td>Vitrify WESF inventory in Phase 2 of WTP and LLW disposal for remaining items. No identified disposition for Oak Ridge RTGs and other items.</td></tr>
<tr><td>2</td><td>Consolidation for Disposition</td><td>Consolidate materials at Hanford to optimize disposition.</td></tr>
<tr><td>3</td><td>National Resource Consolidation</td><td>Consolidate materials at Hanford and manage for commercial use or national resource reserve.</td></tr>
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<tr><td>5</td><td>Disposition Before Consolidation</td><td>Reduce inventory of material through LLW disposal and consolidate remaining items at Hanford.</td></tr>
<tr><td>6</td><td>Secure Sub-Surface Storage</td><td>**Transfer WESF inventory to a secure, long-term, underground storage facility at Hanford. LLW disposal for remaining items. No identified disposition for Oak Ridge RTGs and some other items.**</td></tr>
</table>

The approach for the Trade Study was to define and evaluate alternatives with respect to the ultimate end state of the material. The three defined end states for the material were defined as:

- High-Level Waste (HLW) Disposal
- Low-Level Waste (LLW) Disposal
- Potential Reuse

The team of subject matter experts did not consider secure, long-term storage as an end state for the WESF capsules in the original Trade Study. However, recent developments within the Department of Energy (DOE) apply a risk-based approach to decisions with potentially substantial cost savings, and secure long-term storage has been recommended for evaluation against the criteria established for the Cs/Sr decision process. The original criteria are used in the analysis where applicable; criteria that have been modified are identified.

3.0 Problem Statement

The problem statement for this addendum is the same as the Trade Study.

> **A DOE complex-wide evaluation of Cs/Sr disposition alternatives should be performed to determine if significant risk reduction or inventory optimization can be achieved through an alternative means of inventory management.**

Assumptions

Governing assumptions developed and included in the Trade Study apply to this addendum. In addition, based on the DOE initiative to evaluate potential cost reducing alternatives with a risk-based approach, the following assumption is included:

- A long-term storage alternative can be demonstrated through performance assessment to be within allowable risk established for the site.

4.0 Issues

Issues relevant to the selection and implementation of a program to manage the disposition of excess Cs and Sr items include site and programmatic aspects, technical, regulatory, commercial, and stakeholder concerns. All of the Hanford specific issues identified in the Trade Study apply to this addendum. In addition, the following issues associated with a long-term secure storage alternative are considered:

- Complete containment of the highly soluble materials in the existing capsules may not be ensured because of the reactivity between the cesium and strontium salts and the capsule and canister materials. (WHC-SD-WM-DP-087)

- The Tri-Party Agreement specifies vitrification for the Cs/Sr inventory and would require modification for different dispositions.

- The Cs/Sr inventory is regulated under RCRA because of the barium and cadmium contaminants and is stored in a RCRA facility. Establishment of a long term RCRA-permitted storage facility would be required.

5.0 Requirements and Goals

The absolute requirements that were established in the Trade Study included non-negotiable conditions used to differentiate between alternatives and screen out unrealistic considerations. These requirements and goals are identified in Table 5-1 and Table 5-2 below.

Table 5-1. Summary of Absolute Requirements
That Shall Be Met for an Alternative to be Considered.

Requirements	Description
Public Safety	All potential risks and impacts must be well understood, and no consequences are permitted that cannot be mitigated by reasonable measures.
Radioactive Waste Management Manual (DOE M 435.1-1)	All alternatives must define disposition paths consistent with procedural requirements and existing practices outlined in DOE M 435 1-1.
Closure Commitment	No re-start of a closed facility for which there is a Departmental, site, or local commitment to keep such facility closed and inactive.
Technical Maturity	All processes, components, all equipment, and technology required to implement any alternative must exist in a reasonable state of maturity. No significant technological or scientific research and development activities are allowed to realize any alternative.

Table 5-2. Decision Analysis Goals Represent the Ideal End State Condition.

Goals	Description
1. Minimize Risk	Minimize the impacts and risk associated with managing the Department's inventory of excess Cs/Sr to workers, the public, and the environment.
2. Minimize Cost	Minimize the cost of managing the inventory from the present until its ultimate disposition.
3. Minimize Programmatic Complexity	Minimize the number of facilities and locations managing these materials.
4. Maximize Reuse	Maximize the potential that inventory would be readily available for reuse options through either commercial applications or for reuse in Federal programs.

Alternative 6 complies with the requirements and goals defined in the original trade study, but considers that a change in definition of the waste type from high-level waste to low-level waste is feasible to consider.

Section 6.0 Methodology

This addendum provides the same level of rigor that was developed and implemented in the Trade Study and in doing so follows the decision analysis methodology steps identified in Figure 6-1.

Section 7.0 Alternative Development

Secure Storage Alternatives

Any long-term storage alternative depends on the ability to contain the material for a long period of time. This may be accomplished by the existing capsule containment, overpacks, or a combination of both. Previous studies have provided some insight into the integrity of the existing capsules.

1. Determine the "Decision Approach."

2. Formally Define Problem.

3. Identify Requirements and Goals.

4. Define Alternatives.

5. Define Discriminating Criteria.

6. Screen Alternatives Against Absolute Requirements.

7. Evaluate Alternatives Against Criteria.

8. Validate Solutions Against Problem Statement.

Figure 6-1. Decision Analysis Methodology Steps.

Long Term Capsule Integrity:
The cesium and strontium capsules (Figure 7-1) were designed to last hundreds of years. The lifetime integrity of these capsules, however, has been deemed uncertain due to the unexpected failure of a capsule that was used commercially. (WHC-SD-WM-ES-382)

Figure 7-1. WESF Cs/Sr Capsule

Long-term cesium studies examined cesium chloride capsules after extended storage at 350°C to 450°C. Linear extrapolations of initial corrosion rates suggested capsule wall failure in 25 to 35 years. Corrosion rates at lower temperatures appeared to be much slower. Moreover, because corrosion appears to result mostly from impurities, it is expected that the rate would decrease as the impurities are consumed.

Long-term strontium corrosion studies found that chemical attack of the Hastelloy C-276 inner
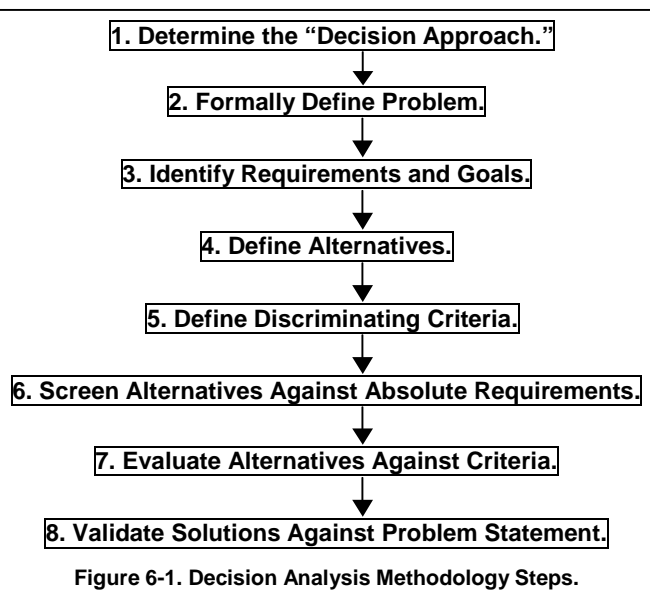
capsule containment material results primarily from impurities in the SrF_2. Once the critical impurities are consumed by the corrosion reaction (up to 12,000 hours), the rate of chemical attack decreases to a low level. Studies conclude that, for heat source applications, maintaining the temperature of the capsule wall below 800°C would adequately contain the SrF_2 for 10 to 20 years. Because the reacting impurities are expected to be consumed by that time, additional corrosion is expected to be minimal. (WHC-SD-WM-DP-087)
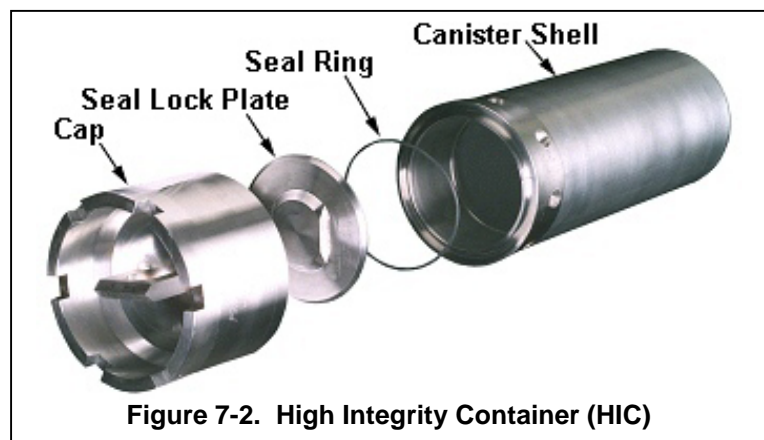

Figure 7-2. High Integrity Container (HIC)

High Integrity Container Storage

High Integrity Containers (HIC) are designed for long-term storage and disposal of low level radioactive waste (Fig 7-2). HIC's are commercially available and have been approved as meeting the requirement for containing waste for 300 years. Industry acceptance of the HIC for long-term storage and disposal of LLW provides a basis for consideration as an interim storage container for the Cs/Sr capsules. The concept for use of HICs includes placement of Cs and Sr capsules into a HIC and placement of the HIC in a secure subsurface storage facility. To facilitate monitoring and surveillance, it was assumed that the long-term storage facility would be similar in construction and operational costs to a RCRA landfill. Cost and ES&H analyses for this concept, similar to those in the Trade Study, are included as Appendix A and B, respectively.

To facilitate handling, inspection, and monitoring of the HIC, this concept considers that the container should provide a maximum dose of 200 mrem/hr at the external surface of the container. This requirement necessitates the use of shielding to reduce the dose at the container surface. In addition, the heat of the capsules must be considered in evaluating material available for shielding.

The HIC concept evaluated for the Cs/Sr capsules is based on the Hastelloy HIC developed under the Nuclear Material Focus Area (NMFA). The NMFA HIC is too small for the capsule containment, thus a similar HIC would need to be designed and manufactured that could store multiple capsules. Preliminary calculations indicate that stainless steel shielding, used as a baseline, should be approximately nine inches thick (see Appendix C) to reduce the dose to the 200 mrem/hr limit established for this concept.

Final design alternatives may consider designing the HIC to include an equivalent nine inches of stainless steel shielding, or reducing the HIC wall thickness and placing a loaded HIC into a concrete overpack container to provide additional shielding and facilitate contact handling. The concrete container would be placed into a retrievable subsurface storage facility. Alternately, the HIC could be designed for remote handling and no concrete overpack would be used. It is assumed concrete would be adequate; design validation, including thermal analyses, would be needed if a decision is made to proceed with this alternative. Concrete overpacks were considered to facilitate handling of the containers with the HIC and provide the primary dose reduction through wall thickness. Concrete overpacks would not necessarily be required and the HICs could be buried directly and handled remotely. A final design should consider the package handling alternatives and may or may not ultimately require concrete overpacks.

For this Trade Study, a HIC would be designed to store ten capsules each, requiring an approximate total of 200 HIC's. A detailed design should optimize the package arrangement and loading. The capsules themselves would provide the primary containment of the Cs and Sr. The HIC would effectively provide a dual containment and have a design life of 300 years. Finally, the concrete shielding container would provide a third barrier against potential release of the material.

Two five packs of capsules could be placed in each HIC. Each HIC would have approximately a two-foot diameter and would be placed into a concrete vault approximately five feet square.

The concrete outer packages would be designed to be retrievable. However, it may also be desirable to design the subsurface storage facility to include underground liners, a leachate collection system, an engineered cap, a long-term monitoring system, and institutional controls. Such a design would provide additional protection and permit monitoring during storage. Preliminary sizing of the facility assumes 200 5'x5' boxes for a surface area of 5,000 sq. ft. The surface area was doubled to provide spacing in support of placement and retrieval for a total of 10,000 sq. ft., which equates to a 100'x100' area for the bottom of the facility. The total depth is assumed to be 20 feet from the ground surface to the bottom; using a 3:1 sideslope results in a top area of 220'x220'. The cap will extend over the sidewall by approximately 10' on each side. Thus, a rough estimate of the storage area is 240'x240' (1.3 acres) which was rounded to 2 acres to support development of cost estimates.
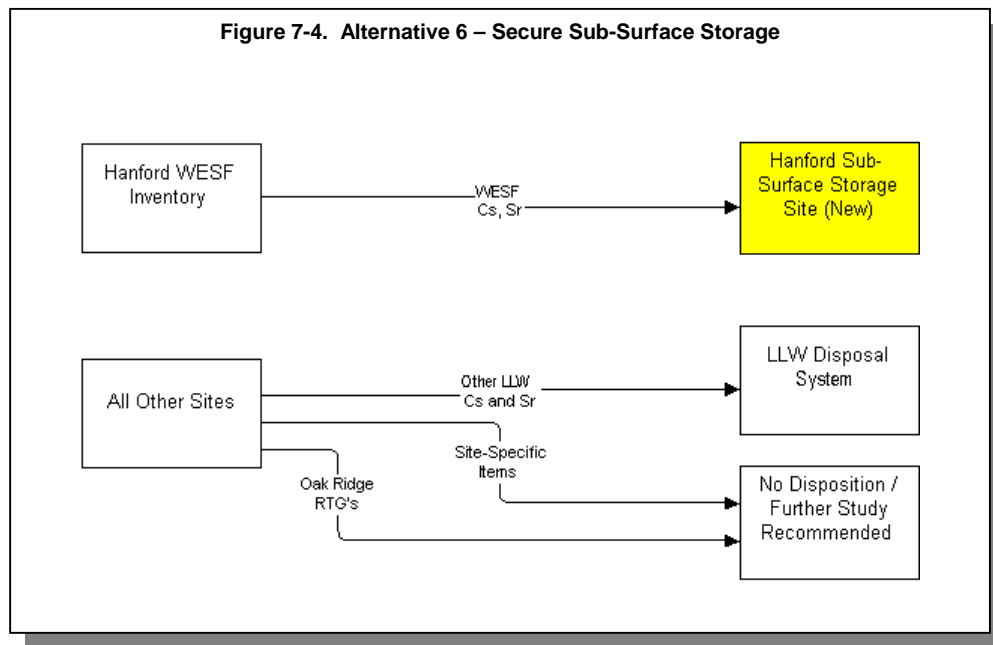
Figure 7-4. Alternative 6 – Secure Sub-Surface Storage

Secure Sub-Surface Storage of WESF Inventory and LLW Disposition of Other Materials

- Prepare and transfer WESF capsules to new HIC and concrete overpack.
- Place capsules in subsurface storage facility.
- Implement long-term monitoring.
- Dispose of majority of non-Hanford inventory as LLW.
- No disposition of Oak Ridge RTGs.

FEATURES	REQUIREMENTS	ISSUES
- WESF is closed. - Containers are retrievable. - WESF material is dispositioned in 8 years.	- Capital cost for subsurface storage facility - Operations cost for subsurface storage facility - Long term maintenance and surveillance costs for subsurface storage facility - New HIC design - Permitting required for RCRA storage facility	- Not all material dispositioned (approx. 1.5 MCi remain) - Containment must be demonstrated through design.

Alternative 6, Secure Sub-Surface Storage, is a modified version of the Baseline Alternative and considers long-term secure storage, rather than vitrification, of the WESF inventory. This alternative uses long-term underground storage in an engineered package and containment cell for the material. Note that after approximately 300 years, the Cs/Sr inventory will have decayed to the point that management and handling requirements for the material would be reduced. . The facility and packages would be designed to support retrieval of the materials at the end of the facility operational period. As in the Baseline Alternative, other materials and sealed sources stored throughout the DOE complex will be disposed as LLW. The six RTGs currently stored at ORNL Building 3517 would remain in their present configuration with no current disposition plan.

Section 8.0 Discriminating Criteria Development

The same weighted criteria used in the original Trade Study to discriminate among the decision alternatives were used in the evaluation of the secure storage alternative. The nine discriminating criteria are applied to this addendum and include:

1. Time to Full Disposition
2. Dose Potential Until Disposal
3. Total Number of Shipments
4. Facility/Complexity of Operations
5. Operational Costs
6. Capital Costs
7. Programmatic Risk
8. Stakeholder Concerns
9. Potential for Reuse

Table 8-1 from the Trade Study shows the normalized weights assigned to each of the four goals, the weighting of criteria associated with each of the goals, and the overall normalized weighting for the nine criteria.

Table 8-1. Hierarchical Weighting of Decision Criteria.

Goal	Goal Weight Factor	Normalized Weight Factor	Criteria Name	Criteria Weight (within each goal)	Normalized Criteria Weight	Calculated Weight Value
Minimize ES&H Risk/Impacts	2*	0.235	Time to Disposition	2	0.200	0.047
			Dose Potential	3	0.300	0.071
			Number of Shipments	1	0.100	0.024
			Facility/Operational Complexity	4	0.400	0.094
Minimize Cost	3	0.353	Operational Costs	1	0.250	0.088
			Capital Costs	3	0.750	0.265
Minimize Programmatic Complexity	3	0.353	Programmatic Risk	2	0.667	0.235
			Stakeholder Issues	1	0.333	0.118
Maximize Reuse Potential	0.5	0.059	Potential for Reuse	1	1.000	0.059

* ES&H is assumed to be conducted in a safe and compliant manner. The weight was established based on this assumption.

Section 9.0 Evaluation of Alternatives Against Discriminating Criteria

The nine discriminating criteria developed from the four goals were used to evaluate and compare the alternatives. The objective is to identify and rationalize any preferred alternative that best satisfies the goals and to determine and understand the relative ranking among the alternatives and their sensitivity to the discriminating criteria. All quantitative calculations involving the criteria weighting, the conversion of criteria metrics into decision-maker utilities, and the calculation of final decision metrics for each alternative were performed using the Quick Compare software package, which is a convenient tool for performing the decision analysis calculations and generating results (Pincock, 2001). The estimation of the criteria metrics, development of the criteria weights by the decision team, and the calculation of the alternatives' decision metrics are discussed in the Trade Study (DOE, 2001a).

For each alternative, a score was assigned to each of the criteria by the decision team, using scores ranging from 1 to 5, although use of the full range for any criterion was not required (see Table 9-1).
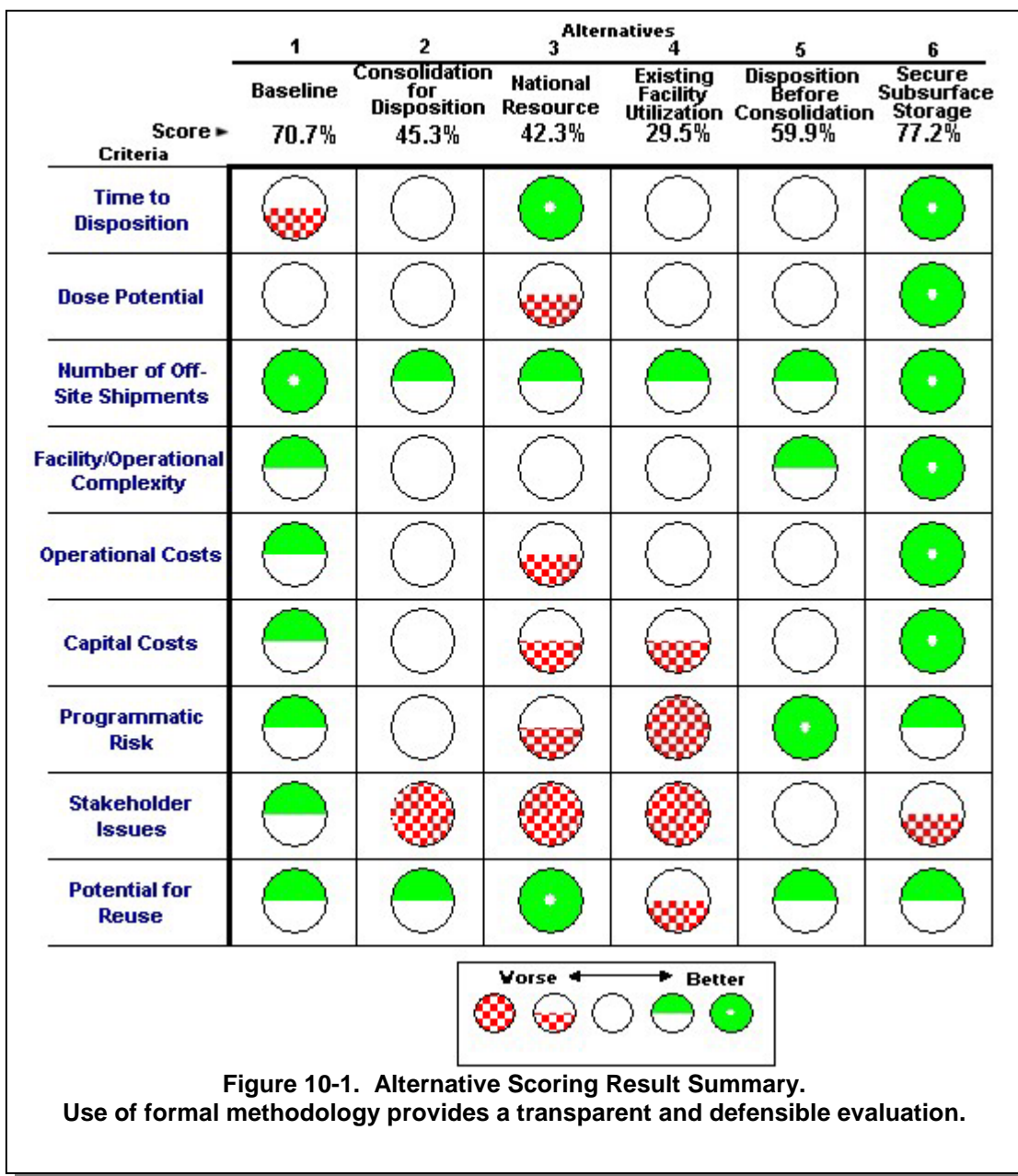
Table 9-1. Scoring Table

Criterion	Weighting k_j	Alternative Criteria Scores (S_{ij})					
		1	2	3	4	5	6
Time to Disposition	0.047	2.00	3.00	4.25	3.00	3.00	4.50
Dose Potential	0.071	3.00	3.00	2.50	3.00	3.00	4.25
Number of Shipments	0.024	4.25	4.00	3.50	4.00	4.00	5.00
Facility/Operational Complexity	0.094	4.00	3.25	3.25	3.25	4.00	4.50
Operational Costs	0.088	4.00	3.25	2.00	3.00	3.25	4.50
Capital Costs	0.265	4.00	2.75	2.50	2.00	2.75	4.75
Programmatic Risk	0.235	4.00	2.75	2.50	1.25	4.25	3.75
Stakeholder Issues	0.118	4.00	1.50	1.75	1.75	3.00	2.25
Potential for Reuse	0.059	3.75	3.75	5.00	2.25	3.50	4.00
Alternative Total Score* (%)		**70.7**	**45.3**	**42.3**	**29.5**	**59.9**	**77.2**

* $S_i = \sum_j k_j u_{ij} = \sum_j k_j \{\{S_{ij} - S_{min})/(S_{max} - S_{min})\}$ with $S_{min}=1$ and $S_{max}=5$.

Section 10.0 Results

The results of the scoring are shown graphically in Figure 10-1. The new long-term secure subsurface storage option developed in this addendum received a higher score than any of the alternatives considered earlier. The high score for Alternative 6 is directly related to the ability to disposition the material quickly using standard packaging and storage techniques. The result is reduced cost through implementation of this low complexity approach. There are potential stakeholder issues that must be addressed to deviate from the Baseline Alternative.

Figure 10-1. Alternative Scoring Result Summary.
Use of formal methodology provides a transparent and defensible evaluation.

Section 11.0 Validation of Results

Figure 11-1 shows the effect of uncertainty in scoring of the criteria on the relative ranking of the six alternatives. The figure shows the result of varying scores assigned to each criterion by plus or minus 20% of the full utility scale, and indicates that a reasonable variation in scoring does not affect the relative ranking of the alternatives.

Figure 11-1. Criteria Scoring Uncertainty Analysis
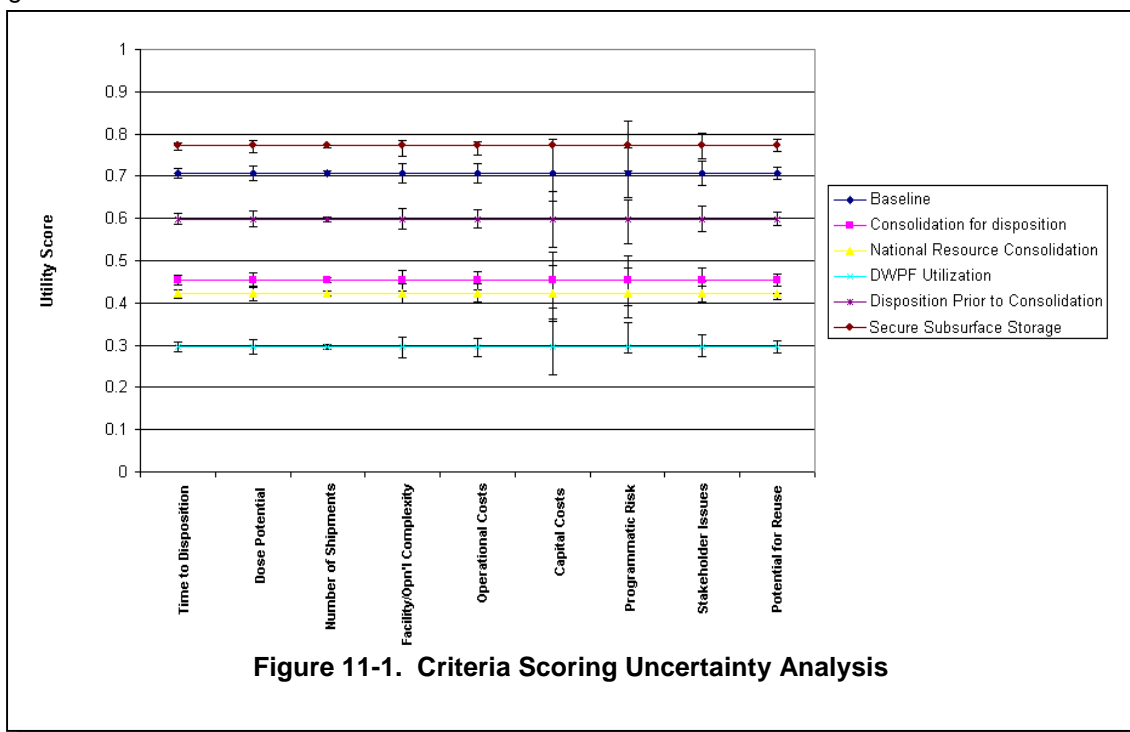
Section 12.0 Summary

The July 2001 Cs/Sr Management Alternatives Trade Study evaluated potential alternatives for the disposition of the complete inventory of excess Cs and Sr within the DOE Complex. The study was conducted under the assumption that the current material designations be maintained with the ultimate end state being disposal as HLW at a HLW repository for the WESF capsules.

Addendum #1 was initiated through a Top Down Review Committee request to address an accelerated risk based approach to the disposition of the Hanford specific WESF Cs/Sr capsules. This addendum applied the established decision methodology used in the earlier Trade Study to evaluate placement of the WESF Cs/Sr capsules into high integrity containers (HIC) and placement of these containers in an secure, onsite subsurface storage facility.

The results of the decision analysis indicate that the long-term subsurface storage alternative is the preferred alternative with a score of 77.2%. The previous preferred alternative was the current baseline with a score of 70.7%.

The secure, long-term storage alternative presents significant cost reduction opportunities and dispositions 99% of the complex-wide Cs/Sr inventory in the most expedient manner. There are clearly some stakeholder issues that would need to be addressed for long-term onsite storage. Considering the potential security and cost saving benefits, a detailed evaluation directed at application of secure subsurface storage is recommended.

References

DOE, 2001a. "Cesium-Strontium (Cs/Sr) Management Alternatives Trade Study," U.S. Department of Energy, July, 2001.

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WHC-SD-WM-DP-087, Preliminary Tank Waste Remediation System Environmental Impact Statement-Engineering Data Package for Disposition of Cesium and Strontium Capsules,"—(used previously for cost estimates.), 1994.

WHC-SD-WM-ES-382. R.D. Claghorn, "Trade Study for the Disposition of Cesium and Strontium Capsules," Westinghouse Hanford, March, 1996.

Appendix A. Cost Analysis for the Cs/Sr Trade Study

The cost analysis for the Cs/Sr Management Alternatives Trade Study has been prepared as a feasibility study level estimate consistent with DOE Guide 430.1. As described in DOE Guide 430.1-1, Chapter 4, "Type of Cost Estimates," Planning/Feasibility Study Estimates, which are used for scoping studies, "are based on past cost experience with similar type facilities, where available, and order of magnitude estimates in the absence of previous cost experience" [DOE, 1997].

The primary cost categories examined were capital, operations, transportation (offsite), and disposal. Capital costs included pre-operational costs, facility design, construction, and facility upgrades. Operations costs captured costs for repackaging, processing, characterization, surveillance and maintenance personnel, and consumables such as utilities and storage. Transportation costs include development of transportation plans, packaging, and shipping to consolidation or processing sites. Disposal costs are specifically for shipment to either a high-level waste repository or low-level waste disposal sites.

Table A-1 summarizes the total costs for the six decision alternatives.

Table A-1. Cost Summary for the Six Decision Alternatives.

Category	Alternative (costs in $ Million)					
	1	2	3	4	5	6
Capital	30	51	50	71	51	17
Operations	193	227	302	227	226	123
Transportation	0	2.6	2.6	20.5	2.6	0
Disposal	0.9	0.9	0.1	0.9	0.9	0
Total Life Cycle Cost	**224**	**281**	**355**	**319**	**281**	**140**

Cost Estimate Assumptions

The following assumptions were made in developing the cost analysis for the Cs/Sr Management Alternatives Trade Study. Assumption 8 has been added for this addendum.

1. All costs are in constant 1999 dollars unless noted otherwise.

2. The life cycle costs extend for a period of 30 years.

3. Due to lack of physical information on materials, it is assumed that shipments will occur in 500-curie increments unless otherwise specified.

4. Activities are conducted at various sites throughout the complex requiring a wide range of labor grades from operations technicians to senior technical staff. For purposes of this study, labor is assumed to be $1,000 per day for fully burdened staff.

5. A range of rates exists for disposal of LLW within the complex. For purposes of this study, disposal is assumed to cost $20 per cubic foot.

6. Intrasite transportation costs are considered incidental.[1]

7. High level waste disposal is estimated at $300K/ton. [DOE, 2001a].

8. The life cycle of the secure storage facility is assumed to be 300 years.[2] After 30 years, maintenance and surveillance costs are assumed minor.

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[1] Intrasite costs are incidental to the decision process because costs for all alternatives will be comparable.
[2] Costs for the long-term storage facility were calculated using present value estimates of long term expenditures. The long term activities would be designed to include primarily data collection from automated systems and minor surface repairs to the storage facility. It can be expected that advanced automation and assessment tools along with improved surfacing materials would reduce labor efforts in the future. There is an uncertainty with inflation in estimating a 300 year activity.

The following provides a summary of the cost elements and total cost for each alternative. The supporting detail for each cost element is included in the Cost Analysis section following the alternatives.

Alternative 6: Secure Surface Storage
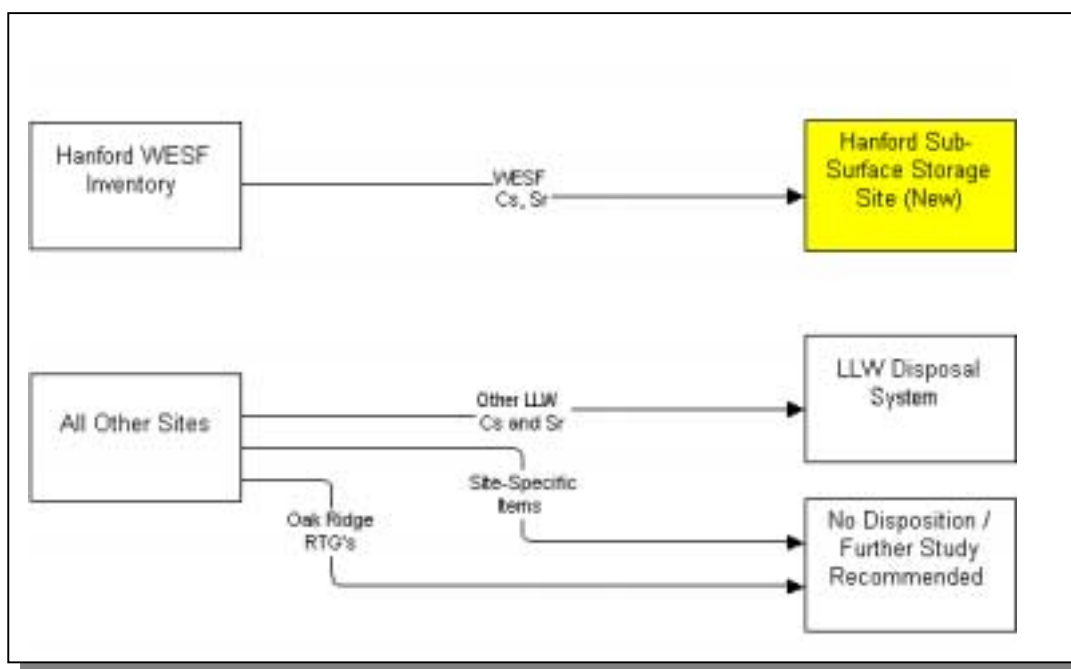
Secure Sub-Surface Storage of WESF Inventory and LLW Disposition of Other Materials

- Prepare and transfer WESF capsules to new HIC and concrete overpack.
- Place capsules in subsurface storage facility.
- Implement long-term monitoring.
- Dispose of majority of non-Hanford inventory as LLW.
- No disposition of Oak Ridge RTGs.

Cost Elements

ID	Description	Cost ($M)	Subtotals ($M)
A	**Maintain WESF**		**88**
F-02	WESF Upgrades	8	
O-05	WESF Operations (8 years; 2001-2009)	80	
B	**Long-term Storage of OR RTGs**		**6**
O-06	Surveillance and Maintenance at OR	6	
C	**Long-term Secure Storage**		**46**
F-07	New Subsurface Storage Facility	7.0	
F-08	EIS For New Subsurface Storage Facility	2.0	
O-13	Complete Facility Safety Authorization Basis	1.0	
O-14	Load WESF Capsules into HIC	20.0	
O-15	Procure Capsule Packaging	3.0	
O-16	Long-Term Monitoring	3.0	
O-17	Long-Term Maintenance	3.0	
O-18	Interim Storage and Placement of HICs in Cell	7.0	
	TOTAL		**140**

Cost Analysis

Primary cost elements have been established for the purpose of this study to identify key program components necessary for the implementation of each alternative. The following cost estimates are consistent with the guidance provided in DOE Guidance Document G430.1, using best available information.

Cost Element

Cost Element	Cost Element Description	Alternative (Costs in $M)					
		1	2	3	4	5	6
F-01	Upgrade OR 3517		$0.6		$0.6	$0.6	
F-02	WESF Upgrades	$8.0	$8.0	$8.0	$8.0	$8.0	$8.0
F-03	OR concrete vault construction					$0.6	
F-04	Hanford WTP Upgrades	$22.0	$22.0		$22.0	$22.0	
F-05	New Storage Facility		$20.0	$20.0	$40.0	$20.0	
F-06	Hanford Processing Facility			$22.0			
F-07	New Subsurface Storage Facility						$7.0
F-08	EIS for Subsurface Storage Facility						$2.0
O-01	Package OR Cs-137		$0.5	$0.5	$0.5	$0.5	
O-02	Package OR Sr-90		$0.3	$0.3	$0.3	$0.3	
O-03	Dismantle/Load 5 RTGs		$0.5	$0.5	$0.5		
O-04	Hanford WTP	$27.0	$27.0		$13.5	$27.0	
O-05	Hanford WESF Operations	$160.0	$160.0	$50.0	$160.0	$160.0	$80.0
O-06	Long term OR capsules storage in 3517	$6.0					$6.0
O-07	Long-term storage of resource inventory			$85.0			
O-08	Hanford WTP processing of OR material		$0.6			$0.6	
O-09	DWPF Vitrification of OR material				$0.6		
O-10	DWPF Vitrification				$13.5		
O-11	New Storage Facility operations		$38.0	$38.0	$38.0	$38.0	
O-12	WESF inventory processing operations cost			$128.0			
O-13	Complete facility safety authorization basis						$1.0
O-14	Load WESF Capsules into HIC						$20.0
O-15	Procure Capsule Packaging						$3.0
O-16	Long-term Monitoring						$3.0
O-17	Long-term Maintenance						$3.0
0-18	Interim Storage/Placement of HICs in cell						$7.0
T-01	Transportation cost		$2.6	$2.6	$20.5	$2.6	
D-01	High-level waste disposal	$0.6	$0.6		$0.6	$0.6	
D-02	Low-level waste disposal	$0.3	$0.3	$0.1	$0.3	$0.3	
TOTAL		$224	$281	$355	$319	$281	$140

Facility Improvements – Capital Costs

F-01	Upgrade OR Building 3517 for processing of OR material into WESF type packages [Eversole, 1999].	
	- Hot cells repairs, upgrades and new equipment	$ 250 K
	- Safety Document Review	$ 50 K
	- Readiness assessment	$ 100 K
	- Procedures and Training	$ 150 K
	TOTAL	**$ 550 K**

F-02	WESF Upgrades (preliminary information; no defined basis) [Reddick, 2001].	
	FY02	$2.3 M
	FY03	$1.0 M
	FY04	$0.9 M
	FY05	$1.8 M
	FY06	$1.0 M
	FY07	$0.3 M
	TOTAL	**$7.3 M**

F-03	Construct concrete vault at OR for long-term storage of the 5 RTGs.	**$600 K**

F-04	Hanford Waste Treatment Plant Phase 2 to support processing and purification of material for vitrification of WESF inventory. (Some processing required for removal of chlorine for commercial use.) [Claghorn, 1996]	
	Capital Cost	**$22 M**

F-05	New Storage Facility.	**$20 M**

F-06	New Hanford Processing Facility. Facility is comparable in size, scope, and cost to F-04, but is not integral to the Waste Treatment Plant.	**$22 M**

F-07[*]	New Subsurface Storage Facility. Lined subsurface storage facility with leachate collection and monitoring systems. Includes design, permitting and construction of cell, support infrastructure and cap. (Based on actual cost of CAMU constructed at Sandia in FY99) • Design $1M • Permitting $1M • Construction of lined storage facility and collection and monitoring systems $3M • Support infrastructure construction (road, power, water, etc.) $1M • Program management and quality assurance $1M	**$7 M**

F-08	EIS for subsurface storage facility	**$2 M**

[*] Preliminary calculations were performed for cost estimating purposes, and assumed a spacing of 10,000 sq.ft. for a 100' x 100' area for the bottom of the facility to provide spacing in support of placement and retrieval of 200 5x5 boxes (surface area of 5,000 sq.ft.). Assuming a total depth of 20' to the bottom of the facility and using a 3:1 sideslope results in a top area of 220' x 220'.

Operations

O-01	Package OR Cs-137 Sources (118 Sources) [Eversole, 1999].	
	- Load sources into 20 WESF or DWPF capsules and weld	$400 K
	- Load into cask and prepare shipment	$100 K
	(5 shipments)	
	TOTAL	**$500 K**

O-02	Package OR Sr-90 Sources (22 Sources) [Eversole, 1999].	
	- Load sources into 12 WESF capsules and weld	$240 K
	- Load into cask and prepare shipment	$ 60 K
	(3 shipments)	
	TOTAL	**$300 K**

O-03	Dismantle 5 RTGs and Load Sources [Eversole, 1999].	
	- Dismantle 5 RTGs	$400 K
	- Load RTG sources into 5 WESF capsules	$100 K
	- Load into cask and prepare shipment	$ 40 K
	(2 shipments)	
	TOTAL	**$540 K**

O-04	Hanford Waste Treatment Plant Operations to support Vitrification of the WESF Inventory [Claghorn, 1996].	
	Operations Cost	**$27 M**

O-05	Hanford WESF operations including surveillance and maintenance until facility inventory has been removed [Reddick, 1999].	
	$10M per year for 25 years	**$250 M**

O-06	Long-term storage of OR capsules in Bldg. 3517 (storage and maintenance) [Eversole, 1999].	
	$200K per year based on current operating cost for 30 years	**$6 M**

O-07	Long-term storage of inventory for use as national resource or commercial use.	
	Cost estimated at ½ the current cost of facility O&M costs of $10M per year for an annual cost of $5M per year. This is based on the assumption that the material is processed and stabilized in a new and efficient storage facility. It is also assumed that half of the inventory is allocated for commercial use. $5M/yr x 17 years operation	**$85 M**

O-08	Hanford WTP processing of OR material includes the receipt, interim storage, and vitrification of the material.	
	- The OR material will be received in WESF type capsules.	
	- Hanford WESF capsules will be the first to be processed in the WTP.	
	- OR capsules will be shipped only after space becomes available in WESF.	
	- It is assumed no additional surveillance and maintenance costs are incurred for interim storage of the OR items.	
	- Processing of Hanford inventory in the WTP is estimated at $27M for 70,000,000 curies. ($0.39 per curie)	
	Oak Ridge will ship 1,500,000 curies @ $0.39/curie.	$600 K
	TOTAL	**$600 K**

O-09	DWPF Vitrification of OR material.	
	Cost assumed the same as processing this material at WTP.	**$600 K**

O-10	DWPF Vitrification.	
	Assume similar process as WTP resulting in similar Rough Order of Magnitude cost of only processing Cs, which is approximately half of the Hanford inventory. (WTP total processing cost of $27M) x 0.5	**$13.5 M**

O-11	New Storage Facility Operations	
	Operations would be comparable to those identified in the dry storage alternative of the Hanford Cs/Sr Trade Study [Claghorn, 1996]. Assume five years until facility is built and operational, i.e., operations begin in 2006. Cost estimated at $2M/year for 17 years.	**$38 M**

O-12	WESF Inventory Processing Operations Cost	
	Commercial proposal received in 2001 identified processing cost of $150 M. Reducing by $22 M in capital costs gives a cost estimate for operations of $128 M.	**$128 M**

O-13	Complete facility safety authorization basis	
		$1M

O-14	Load WESF Capsules into HIC	
	Load capsules into HIC and load HIC into concrete overpack. Assumes 5 year operation with 10 FTE's	**$20 M**

O-15	Procure Capsule Packaging	
	Design and procure HIC and concrete overpack. Includes design, certification, manufacturing and procurement of 200 each HIC's and overpacks. HIC's estimated at $5K each and overpacks estimated at $2K each.	**$3 M**

O-16	Long-term Monitoring	
	Cost of obtaining, analyzing, and archiving data for the life cycle of the facility. Estimated at $10K per year for 300 years.	**$3 M**

O-17	Long-term Maintenance	
	Cost of performing preventive and corrective maintenance of the monitoring system, cap, and facility infrastructure. Estimated at $10K per year for 300 years.	**$3 M**

O-18	Interim Storage and Placement of HICs in Cell	
		$7 M

Transportation

T-01	Transportation cost includes all labor and materials for packaging, characterization for shipping purposes, and shipment. The total number of shipments in each alternative is based on the transportation analysis in the ES&H section of this study.	
	• Labor and materials for packaging. - Assume 30 man-days to gather material, package, prepare bill of lading, etc., per truck @ $1,000 per man-day	$30 K
	- One truck holds approximately 80 55-gallon drums. Assume each truck is full. 80 drums @ $50/drum = $4,000 per truck	$4 K
	- Characterization is difficult to estimate in general terms with the numerous types and physical forms of items. For purposes of this study, it is assumed that sampling of 10% of the waste is required.	
	• Obtain sample @ $2,000	
	• Analytical cost @ $2,500	
	• Data verification and validation @ $1,500	
	Total sample cost $6,000	
	8 samples per truck @ $6,000	$48 K
	Shipping cost is based on the assumption that each trip is 1,500 miles one way. Cost per mile is based on commercial vehicles used for LLW disposal shipments from Sandia. Cost per mile is $5.90 as established by the National TRU Program for TRUPACT II shipments.	$9 K
	Total cost per shipment	**$91 K**

Disposal

D-01	High-level waste disposal is estimated at $300,000 per ton [DOE, 2001a]. Total material resulting from processing Cs/Sr is estimated as 2 tons.	**$600 K**

D-02	Low-level waste disposal includes the actual disposal cost per cubic foot of waste. Due to the numerous types of waste physical forms and lack of dimensional data, disposal is estimated on a per truck basis using drum equivalents.	
	• One truck holds approximately 80 55-gallon drums.	
	• Each 55-gallon drum contains 7 cubic feet of waste.	
	• Each truck consists of 560 cubic feet of waste.	
	Total disposal cost per truck 560 x $20 = $11,200	**$11 K**

Appendix B. ES&H Analysis

The analysis was based on the same set of simplifying assumptions as used in the Cesium-Strontium (Cs/Sr) Management Alternatives Trade Study, including:

- Movement of material from WESF to long-term secure storage facilities will require 100 trips each for Cs/Sr.

Table B-1. ES&H Risk/Impacts Criterion Estimates.

	Alternative	Time to Full Disposition	Dose Potential Until Disposal (% of available curies.)	Number of Shipments	Facility / Operations*	
					Facility Construction	Complexity of Operations
1	Baseline	1	0.455	206	5	5
2	Consolidation for disposition	4	0.455	234	4	4
3	National Resource Consolidation	3	0.754	270	1	1
4	DWPF Utilization	4	0.375	235	3	2
5	Disposition Before Consolidation	4	0.450	233	4	2
6	Secure Sub-Surface Storage	3	0.455	206	4	4

NEPA Considerations

Alternative 6– Long-term Secure Sub-Surface Storage

The TWRS EIS considered the concept of an underground secure facility for onsite disposal of the capsules. The concept is further refined in this addendum and modified from a disposal facility to long-term secure storage. It may be possible to amend the TWRS EIS in lieu of creating a new EIS. More likely, however, as a new facility, a new EIS will be required. With the fundamental changes in the definition of HLW required for the long-term secure storage concept, additional investigation of the NEPA requirements will be needed.

Siting, construction/modification, and operation of packaging and unpackaging facilities and large storage facilities for waste normally require at least an environmental assessment. Since this alternative involves a new storage facility at Hanford, an environmental assessment for that aspect of the alternative would likely be required.

Appendix C

Memorandum, Sanchez, L.C. to J.A. Jones, "Simplified Shielding Calculations for ^{137}Cs and ^{90}Sr Sources (memo4039 Rev B)," dated January 31, 2002, (5 pages, excluding appendices).

date : January 31, 2002
to: J.A. Jones, Org 6849, MS-0779

from: L.C. Sanchez, Org 6849, MS 0779, PH-(505)844-1369

subject: Simplified Shielding Calculations for ^{137}Cs and ^{90}Sr Sources   (memo4039 Rev B)

Introduction
A series of simple one-dimensional shielding ("point kernel") calculations were performed for ^{137}Cs and ^{90}Sr sources. These sources are the Hanford sources identified in Tables 1 and 2. The shielding calculations are for the attenuation of high-energy photons (gamma-ray) through stainless steel shielding material. A thorough description of the point kernel shielding calculations in presented in Appendices A and B.

Description of Analysis
The maximum surface dose rate for a cylindrical waste package is at it mid-height plane. A simple approximation, which gives reasonable estimates, is a spherical geometry about a point source. This gamma flux for a given gamma-ray source is given by Equation 1.

$$\phi_0 = \frac{S}{4\pi R^2}$$ (*Eq. 1*)

where:

ϕ_0 = x-ray flux of the unshielded uncollided flux   (γ/cm^2-sec)
S = gamma-ray source term   (γ/sec)
R = radius (distance) from surface   (cm)

The gamma-rays are attenuated in shielding materials due to atomic interactions (Compton scattering, photoelectric effect, etc.,) with electrons in the target. A simple, yet effective, model for these radiation effects is the "point kernel method" (if the reader is not already familiar with this method, the reader should immediately read Appendices A and B, which are self-contained tutorials on this analysis method). Using this method, the expression for the attenuation for the uncollided component of transported beam (mono-energetic planar x-ray flux perpendicular to a one-dimensional slab) is given by:

$$\phi = B\phi_0 e^{-\left(\frac{\mu}{\rho}\right)_a \rho t}$$ (*Eq. 2*)

where:

ϕ = gamma-ray flux for a shielded uncollided planar flux   (γ/cm^2-sec)
ϕ_0 = gamma-ray flux of the unshielded uncollided planar flux   (γ/cm^2-sec)
B = scattering buildup factor   (--)
$(\mu/\rho)_a$ = linear mass attenuation coefficient for target material   (cm^2/gm)
ρ = density of target material   (gm/cm^3)
t = thickness of the target material slab   (cm)

The dose rate is determined from the gamma-ray flux by using Equation 3.

$$\dot{H} = C_d f Q \phi$$ (*Eq. 3*)

where:

$\dot{H}$ = dose equivalent rate [rem/hr]

C_d = flux-to-dose conversion factor $[(cm^2 - \sec/\gamma)x(R/hr)]$

f = exposure to absorbed dose conversion ratio [rad/R]

Q = quality factor [rem/rad]

ϕ = gamma-ray flux density $[\gamma/cm^2 - s]$

Mass energy absorption and mass attenuation coefficients are obtained from Tables A-3 and A-4 by linear interpolation. These values are presented in Table 3. Dose rate conversion factors are calculated from relationships from Appendix A and are presented in Table 4.

Calculated Relaxation Lengths for ^{137}Cs and ^{90}Sr

Results

Calculated values for relaxation lengths for gamma-rays from ^{137}Cs and ^{90}Sr sources traveling through stainless steel are presented in Table 5. These values are calculated using mass attenuation coefficients derived from Table A-4. As can be seen from Table A-4, the mass attenuation coefficients are relatively similar for various materials, thus the overall attenuation coefficient is directly proportional to the density of the shielding material. This means that shielding results generated in this section (for stainless steel material) could be linearly scaled by material density to estimated equivalent shielding thickness of other materials. Thus, an equivalent shielding thickness of lead would be equal to a steel thickness multiplied by the ratio of steel to lead densities.

Calculated values for buildup factors for the relaxation lengths from Table 5 are presented in Table 6. With these values, the final set of calculations (using Equations 1, 2, and 3) for gamma flux and dose rates are presented in Table 7 and Figure 1 (selected results only).

Conclusions

The dose rate results from Table 7 indicate that the cesium and strontium sources under study in this analysis are very large. These sources would require substantial shielding in order to reduce the waste package surface dose rate to a "contact-handled" level (200 mrem/hr). These results suggest that monitored retrieval storage could be accomplished by one of the following: storage options: 1) underwater storage, 2) aboveground water storage in a massive concrete/steel structure, or 3) within a transportation container (BUSS cask).

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Table 1. Cesium and Strontium Capsule Data as of December 31, 2000

Capsule Type	Maximum Wattage (w)	Average Wattage (w)	Minimum Wattage (w)	Median Wattage (w)	Maximum Activity (kCi)	Average Activity (kCi)	Minimum Activity (kCi)	Median Activity (kCi)
Cesium	227.54	167.80	109.64	167.09	47.38	34.94	22.87	34.79
Strontium	545.63	225.71	25.60	220.62	80.81	33.39	3.75	32.55

Table 2. Inventory Data for Cs and Sr

	Sen Moy Telcon as of 1/30/2000		DOE/RW-0006 9/30/1996	
Type	Capsules	Curies (MCi)	Curies (MCi)	Thermal Power (kW)
Sr	601	21	43.9 [1]	146.8
Cs	1335	47	98.9 [2]	239.8
Daughters	--	66		
Total	1936	134	142.8	386.6

(1) 21.94 MCi ^{90}Sr and 21.94 MCi ^{90}Y = 43.9 MCi.
(2) 50.78 MCi ^{137}Cs and 48.09 MCi ^{137m}Ba = 98.9 MCi.

Table 3. Mass Energy-Absorption and Mass Attenuation Coefficients

Nuclide	Gamma-ray Energy (MeV)	Mass Energy-Absorption Coefficient $(\mu_a/\rho)^x$ (cm^2/g)		Mass Attenuation Coefficient $(\mu_s/\rho)^x$ (cm^2/g)	
		Air	Tissue	Concrete	Iron
^{137}Cs	0.66165	0.0294	0.0317	0.0774	0.0732
^{90}Sr/^{90}Yr	1.761	0.0247	0.0266	0.0479	0.0453

Table 4. Dose Rate Conversion Factors

Nuclide	Gamma-ray Energy (MeV)	Flux-to-Dose Conversion Factor $C_d = 0.0659E\text{-}03$ $E_\gamma(\mu_a/\rho)^{air}$ (cm^2-sec/γ)x(R/hr)	Exposure-to-Absorbed Dose Conversion Factor $f = 0.874 (\mu_a/\rho)^{tissue} / (\mu_a/\rho)^{air}$ (rad/R)	Quality Factor Q (rem/rad)
^{137}Cs	0.66165	1.282E-06	0.942	1.0
^{90}Sr/^{90}Yr	1.761	2.866E-06	0.941	1.0

Table 5. Calculated Relaxation Lengths for ^{137}Cs and ^{90}Sr							
Gamma Energy (MeV)	**Mass Attenuation Coefficient $(\mu_s/\rho)^x$ (cm^2/g)**	**Relaxation Length Shielding Thickness of Stainless Steel (cm)**					
		0.0 (0.0 in)	**5.0 (1.97 in)**	**10.0 (3.94 in)**	**15.0 (5.91 in)**	**20.0 (7.87 in)**	**25.0 (9.84 in)**
0.66165	0.0732	0.00	2.94	5.87	8.81	11.74	14.68
1.761	0.0453	0.00	1.82	3.63	5.45	7.27	9.08

Table 6. Calculated Buildup Factors for Given Relaxation Lengths for ^{137}Cs and ^{90}Sr							
Gamma Energy (MeV)	**Mass Attenuation Coefficient $(\mu_s/\rho)^x$ (cm^2/g)**	**Buildup Factor Shielding Thickness of Stainless Steel (cm)**					
		0.0 (0.0 in)	**5.0 (1.97 in)**	**10.0 (3.94 in)**	**15.0 (5.91 in)**	**20.0 (7.87 in)**	**25.0 (9.84 in)**
0.66165	0.0732	0.00	4.49	7.60	10.36	12.89	15.27
1.761	0.0453	0.00	2.36	3.98	5.43	6.76	8.00

Table 7. Dose Equivalent Rates for Various Shield Thickness								
Source (nuclide / Emission)	**Activity (Ci)**	**γ Flux at m. from Source (γ/cm^2– sec)**	**Dose Equivalent Rate (REM/hr) Shielding Thickness of Stainless Steel (cm)**					
			0.0 (0.0 in)	**5.0 (1.97 in)**	**10.0 (3.94 in)**	**15.0 (5.91 in)**	**20.0 (7.87 in)**	**25.0 (9.84 in)**
^{137}Cs 94.6% β$^-$ 0.514 MeV γ 0.66165 MeV 5.4% β$^-$ 1.176 MeV	1.0	2.79E+05	0.336	0.080	7.22E-03	5.20E-04	3.46E-05	2.16E-06
	22.87E+03	6.37E+09	7,7693	1,826	165.	11.9	0.79	4.95E-02
	34.94E+03	9.73E+09	11,753	2,790	252.	18.2	1.21	7.56E-02
	47.38E+03	1.32E+10	15,937	3,783	342.	24.6	1.64	0.103
^{90}Sr 100.0% β$^-$ 0.546 MeV ^{90}Yr 1.43E-6% γ 2.186 MeV 0.011% γ 1.761 MeV + β$^-$	1.0	3.24E+01	8.73E-05	2.07E-05	9.22E-06	2.04E-06	4.11E-07	7.96E-08
	3.75E+03	1.21E+05	0.328	7.78E-02	3.46E-02	7.64E-03	1.54E-03	2.99E-04
	33.39E+03	1.08E+06	2.92	6.92E-01	0.308	6.80E-02	1.37E-02	2.66E-03
	80.81E+03	2.62E+06	7.06	1.68	0.745	0.165	3.32E-02	6.43E-03

(a) Using a specific gravity of 8.02 for stainless steel/iron.

Dose Equivalent Rate for a 47.38 kCi ^{137}Cs Source
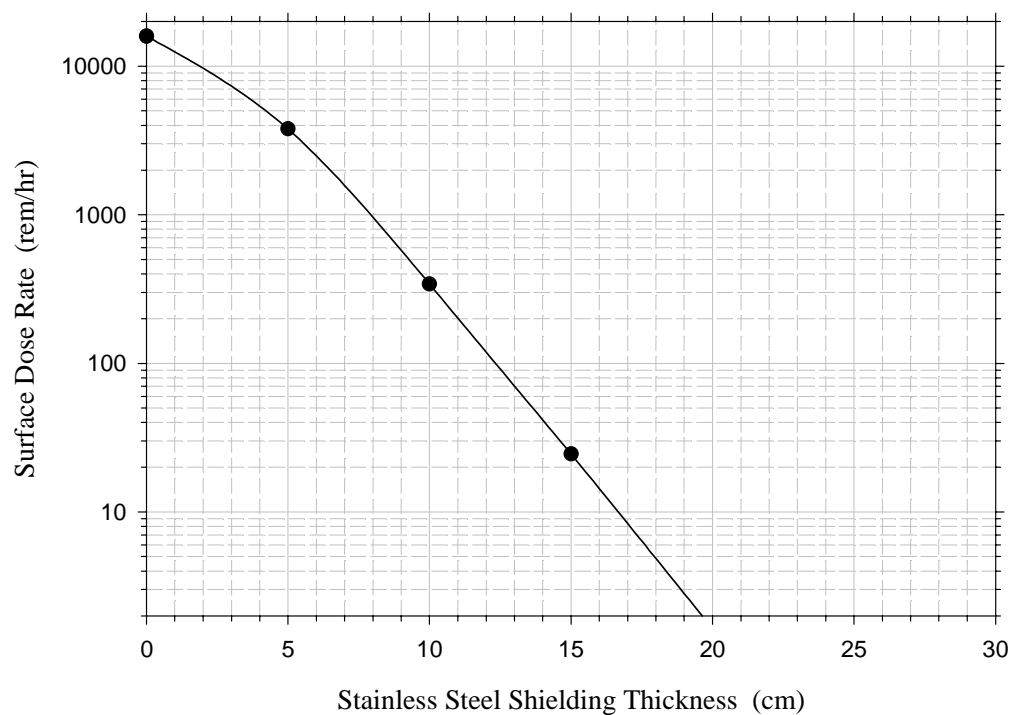(Dose Rate at 1 Meter, Shielded by Stainless Steel)

Figure 1. Dose equivalent rate for a 47.38 kCi ^{137}Cs source as a function of shielding thickness. Shielding material is stainless steel (modeled by iron of specific density 8.01) and dose rate corresponds to a distance from a point source of 1 meter.